19 ORGANIC MANURES

Environmental issues and the concern over the sustainability of the present national agricultural systems have stimulated interest in the integrated use of organic manures and chemical fertilizers. China for centuries has made the best use of recycled organic matter, animal manure, night soil, and composted crop residue. Even after the introduction of high-yielding varieties of cereals and the consequent use of large amounts of chemical fertilizers (China now ranks first in the consumption of nitrogen and phosphatic fertilizer), Chinese agriculture continues to use organic manures (Figure 19.1), providing sustenance to this enterprise. Long-term experiments in India (Sarkar et al., 1989) have also clearly shown that sustainable crop production is possible only when farmyard manure (FYM) is applied along with balanced NPK fertilization and lime (on acidic soils) (Figure 19.2). The U.S. Congress appropriated over $8 million to the U.S. Department of Agriculture (USDA) in recent years for research on a program known as Low-Input Sustainable Agriculture (LISA), which includes substitution of legumes in rotation with other crops to supply N, integrated livestock enterprises to supply manure as a nutrient source for crops, and the use of mechanical-biological pest control.

Organic manures include materials largely of plant or animal origin in different states of decomposition that are added to soil to supply plant nutrients and improve soil physical properties. Organic manures include animal manure, crop residues, logging and wood manufacturing residues, industrial organic wastes such as those from paper and sugar industries, sewage sludge, and residues from the food-processing industry. In the United States estimates of organic residues are at about 694 million metric tons per year (Table 19.1). Typical values for chemical composition for a number of organic wastes are presented in Table 19.2.

19.1. CROP RESIDUES

About 1000 million tons/annum crop residues are globally produced from cereals alone. In addition, there are crop residues from fiber crops such as cotton and linseed, sugar crops such as sugarcane and sugar beet, and grain

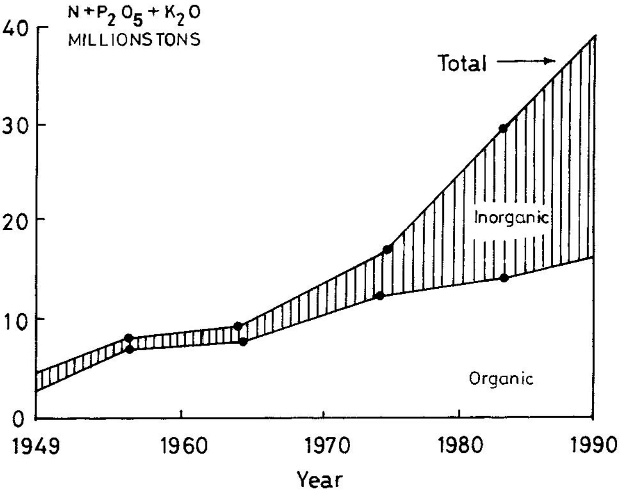

Figure 19.1. Trends in nutrients applied as organics and inorganics in Chinese agriculture. (From vonUexkull and Mutert, 1993.)

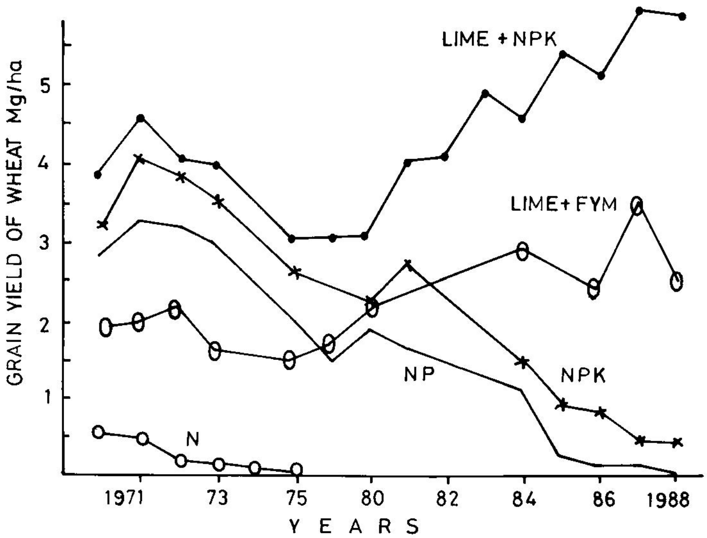

Figure 19.2. Grain yield of wheat at Ranchi (India) as affected by fertilization with N, NP, NPK, lime + NPK, and lime + FYM. (From Sarkar et al., 1990. Fert. News, 34(4):71–80.) With permission.

Table 19.1 Principal Organic Residues in the United States, Their Annual Production, Percentage of Production Applied to Soils, and Percentage of the Particular Residue to All Organic Residues

Organic residue	Total production per year: Thousands of metric tons (dry-weight basis)	Percentage of each residue applied to soils	Percentage of all residues produced
Crop residues	448,740	68	70.4
Animal manures	158,700	90	23.0
Logging and wood manufacturing residues	32,390	5	4.7
Industrial organic residues	7,450	3	1.0
Sewage sludge and septage	3,960	23	0.5
Food-processing residues	2,900	13	0.4
Total	694,179		100

From USDA (1978).

Table 19.2 NPK Content of Some Organic Manures/Residues (% Dry Weight)

Manure/residue	Nutrient content: N	P_2O_5	K_2O
Animal manure			
Cow dung	1.23	0.55	0.69
Buffalo dung	1.91	0.56	1.40
Pig manure	2.80	1.36	1.18
Chicken manure	3.77	1.89	1.76
Duck manure	2.15	1.13	1.15
Agricultural wastes			
Rice straw	1.70	0.37	2.92
Sugarcane	0.55	0.09	2.39
Corn cobs	0.53	0.15	2.21
Beans	2.30	0.54	2.92
Agro-industrial wastes			
Sugarcane	0.87	0.25	0.98
Saw dust	0.51	0.16	0.43
Coconut hull	0.61	0.14	2.03
Chaffs (e.g., pineapple)	1.23	4.03	1.29
Municipal waste			
Household garbage	0.98	1.04	1.06

From Schumann. 1994. Agrochemicals, News in Brief 17(2):24–31. With permission.

legumes. With the widespread use of the combine harvesters in developed countries, crop residues remain in the field and must be managed to provide the greatest advantage possible, especially for water conservation, erosion control, and maintenance of soil organic matter. In some developed countries (United Kingdom, Canada, and Australia) wheat straw is often burned, whereas in other countries (such as West Germany) there are strict laws against burning (Staniforth, 1979).

In less affluent countries, such as those in southern Asia and Southeast Asia, grain is directly used for human consumption, and crop residues are the main source of fodder for animals. In addition, residues from crops such as pigeonpea and cotton are used as cooking fuel and thatching for dwelling huts and cattle sheds.

In many regions of the United States leaving cereal residues in situ has been utilized to control soil erosion and conserve water (Prasad and Power, 1991). Tillage and planting machinery were developed and widely used for this purpose. When adequate weed control is achieved on well drained soils, crop yields of no-tillage are usually similar to or better than those obtained with conventional tillage, especially in drier regions. In wetter and cooler regions of the world or on poorly drained soils, crop yields may be lower when crop residues are left in situ and no preplanting tillage is practiced. In general, leaving crop residues on the surface as in no-tillage farming results in an accumulation of organic carbon, total N, available P, K, and some other plant nutrients in the surface 5 cm of soil.

A number of workers have also reported improvement in many soil physical properties resulting from leaving crop residues in the field (Prasad and Power, 1991). In those countries where crop residues are routinely removed for use as fuel or bedding, soils eventually become depleted in soil organic matter and less desirable physical properties usually develop.

19.2. ANIMAL MANURES

Most countries have fairly large numbers of livestock, which excrete millions of tons of dung and urine. Global estimates indicate that there are 1707 million heads of sheep and goats, 1279 million head of cattle, 149 million head of buffalo, and 12107 million chickens (FAO, 1994). Obviously, large amounts of excreta are produced, which if properly utilized can contribute significantly toward meeting the need for plant nutrients and for building up soil fertility. In the United States, an estimated 175 million tons of manure are excreted each year by all domestic livestock and poultry (Table 19.3). Nitrogen content in animal manure (dry weight basis) varies from 3 to 4% in poultry to 1 to 2% in beef/dairy cattle, while P content varies from 1 to 2% in poultry to 0.2 to 1.0% in beef/dairy cattle (Table 19.4).

In the United States, 65% of the dairy cattle, 80% of the swine, and nearly all poultry are fed in confinement. However, because of the large number of animals involved (over 30 million head annually), confined, beef-cattle feed-

Table 19.3 Annual Total and Confined Production of N and P in Livestock and Poultry Manure in the United States and the Fertilizer Value

	Beef	Dairy	Swine	Poultry	Turkey	Total
Total production						
Number of head (million)	189.3	10.3	55.5	1044.3	73.8	
Manure produced (million ton)						
N	10.65	0.98	0.83	0.43	0.10	12.99
P	3.44	0.17	0.29	0.13	0.04	4.07
Fertilizer value (million $)[a]						
N	4696	432	368	188	44	5728
P	3487	175	294	129	37	4122
Confined production						
Number of head (million)	11.5	10.0	51.5	1021.0	73.8	
Manure produced (million ton)						
N	0.64	0.94	0.76	0.41	0.10	2.85
P	0.21	0.17	0.27	0.12	0.04	0.81
Fertilizer value (million $)[a]						
N	287	416	336	184	44	1267
P	212	166	276	120	37	811

[a] N at \$0.45 kg^{-1}; P at \$1.03 kg^{-1}.

From USDA (1990); White (1989).

lots are the primary source of livestock manure in the United States. Consequently, environmentally safe utilization or disposal of livestock manure is an important public concern. The safest way of utilization is incorporation in soil. Barnyard manure, because of its water content, has a fertilizer grade often less than 1-0.7-1 (Miller and Donahue, 1992). However, when applied in quantities such as 20 tons/ha/yr, manures can add substantial amounts of plant nutrients. Moreover, because they also contain substantial amounts of micronutrients, continuous use of organic manures is a good prophylactic measure against micronutrient deficiencies that may result from continuous use of high-analysis chemical fertilizers. This is well supported by the data from many long-term experiments such as those conducted in India (Nambiar, 1994).

Use of livestock manure as a nutrient source for crop production is not without problems. The low nutrient content of manure restricts greatly the

Table 19.4 Typical Composition of Selected Animal Manures (Dry-Weight Basis)

Constituent	Beef/Dairy (%)	Poultry (%)	Swine (%)	Sheep (%)
Nitrogen (N)	2–8	5–8	3–5	3–5
Phosphorus (P)	0.2–1.0	1–2	0.5–1.0	0.4–0.8
Potassium (K)	1–3	1–2	1.0–2.0	2.0–3.0
Magnesium (Mg)	1.0–1.5	2–3	0.08	0.2
Sodium (Na)	1–3	1–2	0.05	0.05
Total soluble salts	6–15	2–5	1–2	1–2

From Miller and Donahue. 1992. *Soils—An Introduction to Soils and Plant Growth*, 6th ed., pp. 196–211. With permission of Prentice Hall of India Put. Ltd., New Delhi.

distance it can be economically transported, often no more than 10 km. Chemical composition of manure is highly variable, so it is difficult to apply a specific amount of nutrients when manure is spread. Mineralization of manure N is dependent on many factors and not well controlled by the producer. Thus there is potential for nitrate leaching.

19.3. COMPOSTING

Composting is the microbiological conversion of biodegradable organic wastes to stable humus by indigenous microflora, including bacteria, fungi, and actinomycetes, which are widely distributed in nature. The major objectives in composting are to stabilize putrescible organic matter, to conserve as much of the plant nutrient and organic matter as possible, and to produce a uniform, relatively dry product suitable for use as a manure. In composting, factors such as C:N ratio of the material, water content, aeration, pH, and ambient temperature regulate the prevalence and succession of microbial population. A number of composting processes have been developed over the world (Gaur and Sadasivan, 1993; Tyler, 1970). These can be broadly classified as either aerobic or anaerobic. Anaerobic decomposition results in only a partial breakdown of organic matter and is generally associated with a disagreeable odor. Adequate aeration is essential in aerobic composting. To achieve optimum aerobic decomposition, the water content of the organic material should be between 50 and 60% (wet weight basis).

In composting there is an intrinsic relationship of temperature and pH variation with time. During the early mesophilic stage, pH decreases to about 5 and fungi are the dominant organisms. However, as the temperature of the composting mass increases (thermophilic stage), there is a corresponding increase in pH, and bacteria and actinomycetes are most active. The maximum pH rises to about 8.0, synchronized with the temperature peak during the thermophilic stage. Thereafter, pH usually levels off at values above 7.0.

Conventional methods of composting require a long period to produce good compost, often 8 weeks or more. Recent research has shown that inoculation with mesophilic cellulolytic fungi such as *Aspergillus niger* and *Penicillium* sp. can considerably hasten the process of composting (Gaur and Sadasivan, 1993). Often 25 to 50% of the carbon and 10 to 40% of the nitrogen in the original material is lost to the atmosphere in the composting process. While composts can be usefully employed in field crop production, they have found more favor with horticultural crops and commercial floriculture and in gardening.

In recent years there has been considerable interest in the use of earthworms for composting. This practice is called vermi-composting (Bhawalkar and Bhawalkar, 1993). Worms used are *Lumbricus rubellus* or some other species. The earthworms are commercially raised and multiplied in shallow wooden boxes (45 × 60 × 20 cm) provided with drainage holes. Compost pits measuring approximately 3 × 4 × 1 m deep are dug with sloping sides, and are filled with organic residues such as straw, animal manure, green wastes, or leaves. The earthworms from the wooden boxes are emptied onto the surface of the compost pits, and the worms immediately bury in the compost, helping decomposition of organic residues. When the compost is used, earthworms are removed and are either kept in wooden boxes for further breeding or are transferred to another compost pit. Worm compost is becoming quite popular in Asian countries.

Studies at Rothamstad Experimental Station in the United Kingdom have also shown that earthworms (*Eisenia foetida*) can break down organic wastes into peatlike materials rich in available nutrients and with good water-holding capacity and porosity (Edwards, 1983). These peatlike materials have considerable potential in horticulture as a plant growth medium. Methods of obtaining maximum waste turnover in 2 to 4 weeks under controlled water and temperature conditions have been developed.

19.4. ORGANIC FARMING

The management in ecofriendly sustainable agricultural systems (a broad term encompassing organic farming) includes the use of vegetative cover as an effective soil and water conservation measure. This requirement is met through the use of no-till practices, mulch farming, use of cover crops, or other such practices. Plant nutrients are provided through organic manures, compost, and legumes. Nutrient recycling mechanisms include the use of crop rotations, crop/livestock mixtures, appropriate tree/crop combinations in agroforestry, and intercropping systems involving use of legumes (Altieri, 1992). Different practices provide different pools and fluxes of carbon and nutrients in the soil and have varying effects on biological activity and biodiversity of soil organism communities. For example, Hendrix et al. (1986) showed that for no-till soils in Georgia (U.S.), biological activity was dominated by fungi and earthworms, whereas the biota of the conventional tilled soils was dominated by bacteria, nematodes, and enchytraeids.

Earthworms have received considerable attention in the context of organic farming, and farming systems (vermi-culture) have been developed (Bhawalkar and Bhawalkar, 1993). In typical agricultural systems, earthworm populations are integral to the functioning of the system, and the agronomic value of earthworms is difficult to define. Direct N contributions of earthworms as a proportion of the annual net mineral N flux ranges from 7.9 to 27.3% for arable crops in the Netherlands, 3.4 to 17.6% for a Polish pasture, and 18 to 24.5% in New Zealand grasslands (Knight et al., 1989). However, it must also be pointed out that earthworms can also contribute toward N losses by denitrification and leaching (Knight et al., 1989). One must therefore look at the overall impact for a given agroecological situation.

In the humid and subhumid/semiarid tropics, all factors involved in crop production variables often operate over a wide range of extremes. Compared with temperate regions, storm events are often more erosive, leaching due to heavy monsoons or other rains may be more intensive, dry periods limiting plant growth are often longer or more extreme, and highly weathered soils with low inherent fertility are more prevalent (Anderson, 1994). Furthermore, decomposition of organic residues is more rapid, and maintenance or enhancement of soil organic matter as a source of plant nutrients is more difficult and demands large and frequent inputs. In these regions the increased soil biological activity and community diversity that results from reduced tillage is offset by the low organic resource base maintaining the biota and soil structure (Figure 19.3). Hence, although the principles of sustainable farming practices generally apply to tropical as well as temperate regions, in practice the opportunities for many tropical farmers to optimize nutrient and organic matter management are limited by environmental as well as social and economic constraints (Anderson, 1994).

Organic farmers rely heavily on composting, manuring, crop rotation, intercropping, mulching, and hand weeding. Many Japanese organic farmers intercrop several vegetables and fruits such as potatoes, sweet potatoes, carrots, eggplants, garlic, leeks, and strawberries (Ahmed, 1994). Gardeners were probably the first to develop organic farming (Tyler, 1970). In the United Kingdom the principle guiding organic farming nutrient inputs is that mineral forms must be water soluble, and composts, manures, and slurries are also allowed (Stickland, 1990). Conventional farming by contrast uses many soluble salts of nutrients that are very easily carried by soil water to the plant.

Crop yields under organic farming are often lower than under conventional farming; in some cases they are significantly lower because inputs for the organic farmer are usually less. With good management, however, yields very close to those obtained in conventional farming can be obtained. In the United Kingdom a conventional 7.0 ton ha^{-1} farmer is expected to produce 5.5 to 6.0 ton ha^{-1} with organic farming on similar soils and with the same crop varieties (Stickland, 1990). In some Japanese studies rice grain yields were even slightly greater with organic than with conventional farming. Data from Japan on

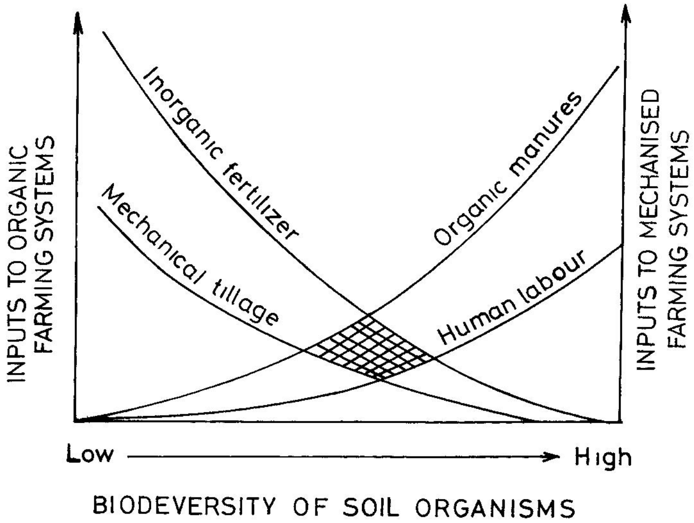

Figure 19.3. Schematic representation of the emergence of soil fauna effects on soil acidity with shift from technology-based agriculture management to production based on organic sources. (From Anderson, 1994. *Soil Resilience and Sustainable Land Use*, D.J. Greenland and I. Szaboles, Eds., pp. 267–289. With permission of CAB International, Wallingford, England.)

vegetable crops are given in Table 19.5. An important feature of organic farming is the premium on quality, especially with vegetables (Table 19.6). When carefully marketed, this can result in a higher price for produce from organic farmers, which can also compensate for lower yields. Consumers in Europe, Japan, and other countries are willing to pay higher prices for agricultural products from organic farms.

The choice of using organic vs. conventional farming depends upon a number of factors, including the availability of land; the population density and the associated demand for food, fiber, feed, and fuel; the resources for gathering and distributing animal manure and other organic residues to farm fields; and the capability of consumers to pay higher prices for farm produce. Also, many choose organic farming because they feel it is more sustainable and does less damage to the environment.

19.5. INTEGRATED NUTRIENT MANAGEMENT

The exclusive and large scale use of chemical fertilizers, occurring after the development of hybrids in the United States and high yielding hybrids/composites/varieties in other parts of the world, is at one extreme, while the concept of organic farming is at another extreme. Because of the

Table 19.5 Yields of Selected Vegetables under Organic and Conventional Farming (Mg ha^{-1})

Vegetable	Miyoshi village (organic farming)	Chiba prefecture (conventional farming)	Miyoshi yield as % of Chiba average
Cabbage	1.3–3.8	4.8	27–79
Onion	0.6–2.0	2.3	26–87
Radish	4.7–4.8	5.0	94–95
Carrot	1.3–1.5	3.7	35–40
Tomato	1.9–3.0	4.0	47–75
Eggplant	0.8–2.8	2.9	27–96
Green pepper	0.8–1.0	3.4	23–29
Cucumber	1.8–2.7	2.6	69–104

From Ahmed. 1994. Agrochemicals News in Brief 17(2):16–23. With permission.

Table 19.6 Quality and Fresh Weight of Lettuce under Organic and Conventional Farming

Farming type	Brix (%)	Reducing sugar (%)	Total vitamin C (mg/100 g)	Nitrate N (ppm)	Fresh weight (kg)
Organic	3.4	1.91	7.5	263	300
Conventional	2.7	1.30	5.5	615	386

From Ahmed. 1994. Agrochemicals News in Brief 17(2):16–23. With permission.

increasing food demand for the world (especially in densely populated countries) and because of the perceived lack of sustainability of present intensive and highly productive farming systems, the best course to follow might be the use of integrated nutrient management systems involving judicious use of both chemical fertilizers and organic manures. This system is currently practiced in China and elsewhere. Integrated nutrient management also includes the use of biofertilizers and legumes in crop rotation. Many publications show that this conjunctive use of nitrogen and other nutrients results in the most efficient use of nutrients. Figure 19.4 shows how the nitrogen needs of agriculture in India can be partly met from sources other than chemical fertilizers.

The common assumption among some environmentalists, soil scientists, and agricultural researchers, and especially among those from privileged countries, is that the next step toward improvement of soil fertility and desired crop production is to introduce so-called low-input sustainable agriculture (LISA) technology. Some of the practices recommended include mulch farming, ley farming, alley cropping, and related practices. The point often overlooked is that low-input technologies are often knowledge-intensive and require many skills in crop management that many farmers do not possess.

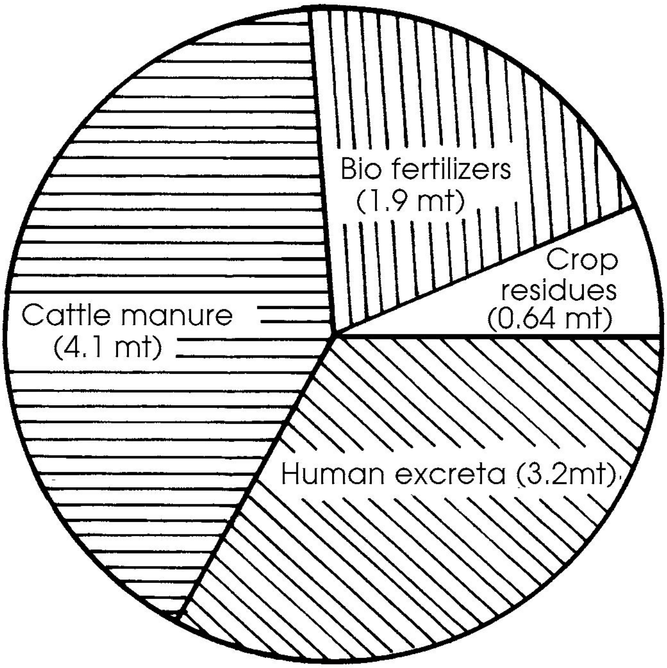

Figure 19.4. Potential of N from organic and biological souces in India. (From Gaur et al., 1984. *Organic Manures*, p. 159. Indian Council of Agricultural Research, New Delhi.)

The large scale use of only organic manure as the sole source of nutrients has several problems. First of all, because of low, variable, and generally unbalanced nutrient contents, it is difficult to provide the proper nutrient balance to meet crop requirements with bulky organic matter. Animal manures create unique problems in application that increase farm workload and management requirements. Bulky, organic manures can be applied only during a few weeks or months each year, usually before seeding or after harvesting a crop. Nutrient deficiencies in crops that arise during the crop growth period can seldom be corrected with bulky, organic manures. Large-scale farmers in advanced countries also find problems in scheduling the application of bulky, organic manures with seeding and other management practices in crop production.

The use of large amounts of animal manures can also lead to environmental problems, especially a buildup of nitrates and phosphates in groundwater. After careful examination of groundwater nitrate data from several agencies in the United States, Spalding and Exner (1993) concluded that the highest incidence of contamination in groundwater occurs in Iowa, Nebraska, and Kansas where nitrate-N levels exceeded 10 mg/1 in 20% or more of the samples collected. In Long Island (New York) the high density

of septic tanks along with the application of fertilizers and manures on agricultural lands probably contributed to high groundwater nitrate-N. Intensive dairy operations with associated problems of manure disposal may be the primary source of nitrates in wells in southeast Pennsylvania and northern Maryland. High nitrate concentrations in Delaware and parts of North Carolina could arise from intensive livestock and poultry operations and from septic tanks (Prasad and Power, 1995). Date on leaching of nitrate-N from a bare soil at Rothamstad Experimental Station in the United Kingdom, as influenced by inorganic and organic manuring, are shown in Table 19.7. Many western European countries have observed high soluble-P concentrations in surface water and groundwater because of continued high application rates of animal manures.

These results and data from a number of other countries indicate that agricultural systems dependent mainly on animal or other bulky organic manures could be difficult to manage. Only a limited number of farmers have the management skills required to make such a system work properly. Also, the quantity of manures available within a suitable transportation distance would often be insufficient to meet the needs of all of the cultivated land. While in cooler climates the decomposition of animal manures may be very slow and may create environmental problems, in warmer, humid climates decomposition is generally too rapid to permit buildup of soil organic-matter content and the nutrient-supplying status of the soil.

The use of chemical fertilizers along with organic manures is probably the best way to keep food production level with or ahead of the increase in the population. For example, in a study at Yurimaguas, Peru (Lavell et al., 1994), organic residues with or without earthworms were studied in maize production. Crop production was sustained at acceptable levels (0.2 to 2.4 tons ha^{-1}) according to local standards, and the use of earthworms showed a definite advantage. However, there was a drastic decline in production from the third year onward (Figure 19.5). This reduction could be controlled only with the application of chemical fertilizers. After application of fertilizers with the crop residues, plots with earthworms again gave higher production. This is an example of conjunctive use wherein a mixture of organic and inorganic nitrogen sources gives better nitrogen-use efficiency than using either source alone.

We would like to conclude this chapter with two sentences from Drs. Borlaug and Christopher (1994). From their keynote lecture at the 15th World Congress of Soil Science held at Acapulco, Mexico, in 1994, we quote, “Indeed, for those concerned with trying to preserve pristine environments or protect endangered species, we would submit that human demographic changes are the greatest threat to the planet Earth in the years ahead. Indeed, if this relentless growth in human numbers goes on unabated, *Homo sapiens* will no doubt end up as an endangered species themselves.”

Table 19.7 Leaching of Nitrate from Bare Soil of the Hoosfield Barley Experiment (Rothamsted) During 1986 and 1987

Treatment	Cumulative leaching loss ($kg\ NO_3\text{-}N\ ha^{-1}$)	Range of NO_3-N concentration in soil at 110 cm during main period of leaching ($mg\ NO_3\text{-}N\ L^{-1}$)
PK[a] + 96 kg N ha^{-1}	25	4–20
FYM[b] + 96 kg N ha^{-1}	124	40–50

[a] PK–35 kg P and 90 kg K ha^{-1} annually since 1984.

[b] FYM at 35 t ha^{-1} annually since 1843; FYM supplied 238 kg N ha^{-1} yr^{-1}.

From Powlson et al. 1989. *Nitrogen in Organic Wastes Applied to Soils*, pp. 334–345. With permission of Academic Press, Orlando, FL.

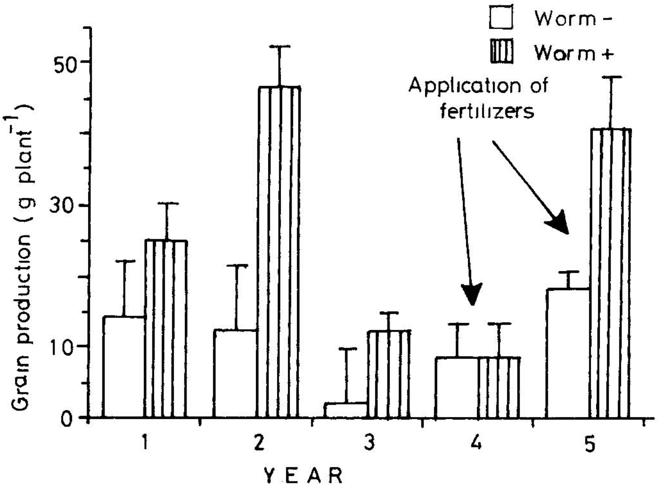

Figure 19.5. Effect of earthworm inoculation on grain production in a continuous corn crop at Yurimaguas, Peru. (Adapted from Lavell et al., 1994.)

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